AD

TECHNICAL REPORT

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STUDY OF A NONDESTRUCTIVE TEST FOR DETERMINING THE VOLUME OF AIR IN FLEXIBLE FOOD PACKAGES

by

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Quality Assurance & Engineering Office

June 1972

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

General Equipment & Packaging Laboratory

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It was found that the results obtained with the nondestructive test correlated favorably with findings of the standard destructive test method and were repeatable (for air volumes not exceeding 30 ml, readings were generally repeated to within 1 ml).

This nondestructive test has the potential for cost savings in testing. Furthermore, it does not require the use of highly skilled technical personnel or elaborate test apparatus.

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Acceptability			7			
Food			9		9	
Specifications					4	
Military Requirements					4	
Determination	4		7			

1B

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Project Reference:
1J662713D552

June 1972

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FOREWORD

This report pertains to a study of a nondestructive test method for measuring the air content in sealed flexible food packages.

The work for this study was performed with materials and equipments available in the Packaging Division of the General Equipment & Packaging Laboratory, U. S. Army Natick Laboratories (NLABS) under Project No. 1J662713D552, Design of Flexible Packaging Systems.

The authors express their appreciation to Mr. L. Klarman, Data Analysis Office, NLABS, for his assistance in programming and compiling the required statistical computations for this study.

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ABSTRACT

A nondestructive method to determine the volume of air in hermetically sealed flexible packages was studied for its applicability as an acceptance test in specifications. Extensive data was obtained with three size packages formed from a flexible laminate material. Packages contained the test medium bentonite as a food simulator.

It was found that the results obtained with the nondestructive test correlated favorably with findings of the standard destructive test method and were repeatable (for air volumes not exceeding 30 ml's, readings were generally repeated to within 1 ml).

This nondestructive test has the potential for cost savings in testing. Furthermore, it does not require the use of highly skilled technical personnel or elaborate test apparatus.

INTRODUCTION

The metal container is currently relied upon to preserve and store foodstuffs for Army use. This traditional method of packaging is being challenged by the flexible package, which may in the future replace the metal can for rations. Currently, programs are being directed at NLABS to develop suitable flexible materials for packaging of food items. In conjunction with these efforts, new tests are also being studied to determine more effectively such characteristics as air (oxygen) content in food packages. It is important to control the amount of air or other gases in flexible packages for the following reasons:

a. Since oxygen in air will affect the preservation of foodstuffs, its control is required to prevent spoilage, thereby assuring safe food for consumption.

b. Excess gas content will contribute to extra bulk and may cause the user to suspect food spoilage.

This report is concerned with the evaluation of a proposed nondestructive test to determine the volume of air within flexible packages containing foods.

The prospects of salvaging quantities of supplies that would normally be expended in a nonrecoverable test procedure justifies investigation of this nondestructive test for possible use in military specifications. This test was originally proposed by Mr. Robert G. Keller, a former employee of the Quartermaster Food & Container Institute of Chicago - the parent organization of the Packaging Division, NLABS. The general principle of this method involves weighing the package while it is suspended in water and then reducing the environmental pressure until the gases in the flexible package expand sufficiently so that the package is in a state of neutral buoyancy; i.e., it neither rises to the surface nor sinks to the bottom. The amount of gas is then computed with an equation derived from Archimedes Principle and Boyle's Law. The equation generally used to determine the volume of air (gas) in a flexible package is as follows when temperature is kept constant and density of water is taken to be 1 gram/1 ml.

$$V_1 = \frac{P_2 (D)}{P_1 - P_2} \quad (1)$$

where:

V_1 = Volume of air (gas) in package at pressure P_1 (ml)

P_1 = Atmospheric pressure at time of test (ins. mercury)

P_2 = Pressure at time package is in a state of neutral buoyancy in water (ins. mercury)

D = Weight of package in water at pressure P_1 (grams)

A detailed derivation of equation (1) is shown in Appendix A.

MATERIALS AND METHODS

Test packages were formed from a laminate material composed of polyester, aluminum foil and polyolefin, and they were shaped as rectangular pouches. The test medium packaged as a food substitute consisted of 8% bentonite and 92% water. A total of 126 to 143 packages was prepared in each of three different sizes to hold 284, 568 and 850 grams of bentonite, respectively. The amount of actual air in the various size packages ranged from 0 ml to 50 ml. The volume of air was initially determined by means of the nondestructive method and then measured by actually opening the package and collecting the air as illustrated in Figure 1. Individual test packages were tested by both methods under the same environmental temperature and barometric pressure conditions. Data results for both methods are listed in Appendix B.

Destructive Test

Although this method is destructive, it is quite simple to execute. As seen in Figure 1, the procedure involves puncturing an opening in the package while it is under water and allowing the sealed air to escape

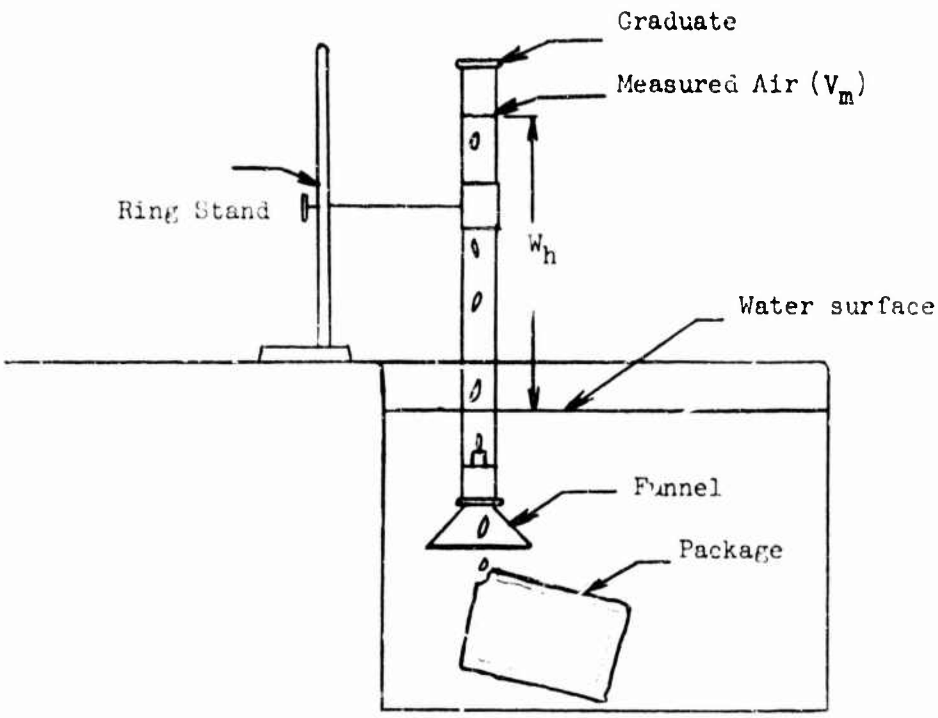

Figure 1 Test Setup for Measuring Air Content in Flexible Package

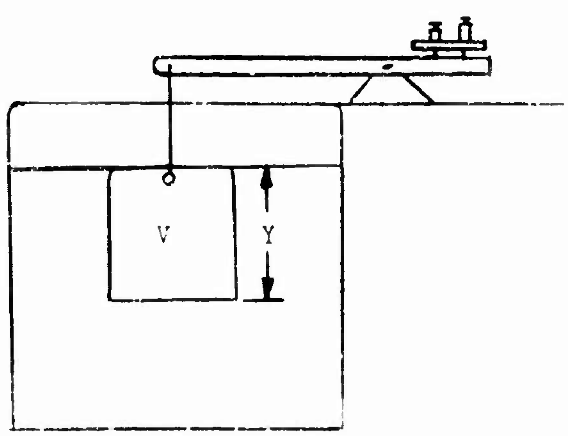

Figure 2 Weighing of Package in Water

into an inverted measuring graduate. Considerable time, however, can be consumed in manipulating and squeezing the contents to assure that all air is forced out of the package. Volumetric measurements of air are corrected to atmospheric pressure as follows by Boyle's Law[1]:

$$V_a = \frac{(P_a - W_h)\, V_m}{P_a} \qquad (2)$$

where:

V_a = Volume of air @ atmospheric pressure (ml)

P_a = Atmospheric pressure (ins. mercury)

W_h = Pressure of water level in graduate (ins. mercury)

V_m = Volume of measured air (ml)

Nondestructive Test

The volume of air hermetically sealed in a flexible package is determined with equation (1). To obtain the required data for this equation, the test package is initially weighed suspended in water, just below the water surface (Figure 2). The weight (D) is expressed in grams. The package is then placed into a transparent cylindrical vessel containing water and checked for leakage. This check is made by creating a high vacuum in the vessel and observing the package for a steady stream of escaping bubbles at leak location. The effect of any air bubbles clinging to the external surface of the package was minimized by the wetting agent in the water. To obtain neutral buoyancy, the vacuum in the jar is decreased gradually allowing the air in the package to expand, causing the package to rise to the surface (Figure 3). The pressure is then carefully increased allowing the package to drop slowly to a neutral buoyancy position just below the water surface. The pressure reading inside the vessel is taken at this point by means of a vacuum gage and is equal to P_2 of equation (1).

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[1] Furry, W. H., E. M. Purcell and J. C. Street. Physics, The Blakiston Co., 1952.

RESULTS AND DISCUSSIONS

The Actual and Calculated (nondestructive) air volume data for the 850-gram package are plotted in Figure 4. (For data tabulation see Appendix B.) These values are treated, both as dependent and independent variables in the analysis. Visual inspection of the pattern and trend of the plotted points suggests that the relationship is essentially linear and is also characterized with a uniform dispersion of points about each regression line. There is a tendency for points to be dispersed slightly more at the higher volumetric levels.

The analysis of variance (ANOVA) technique was used to verify the linearity of the relationship in Figure 4.[2] The ANOVA performed with data for the 850-gram package is summarized in Table I. The Actual and Calculated values were treated as the X and Y variables, respectively.

Table I Analysis of Variance for Air Content in 850-Gram Package

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio
Explained by linear regression	1	12841.134	12841.134	17675.706
Unexplained (Deviations about regression line)	129	93.716	.726	(Critical F @ 95% 1,129 = 3.92)
Total	130	12934.850		

The F ratio of 17675.706 is considerably higher than the critical F of 3.92 indicating quite conclusively that there is a strong linear relationship between the Actual and Calculated readings. The probability is virtually zero that so much of the total variance as explained by linear regression is due to pure chance. The data for the 284 and 568-gram packages in

[2] Dixon, W. J., and F. J. Massey, Jr., Introduction to Statistical Analysis, McGraw-Hill Book Company, Inc., 1957.

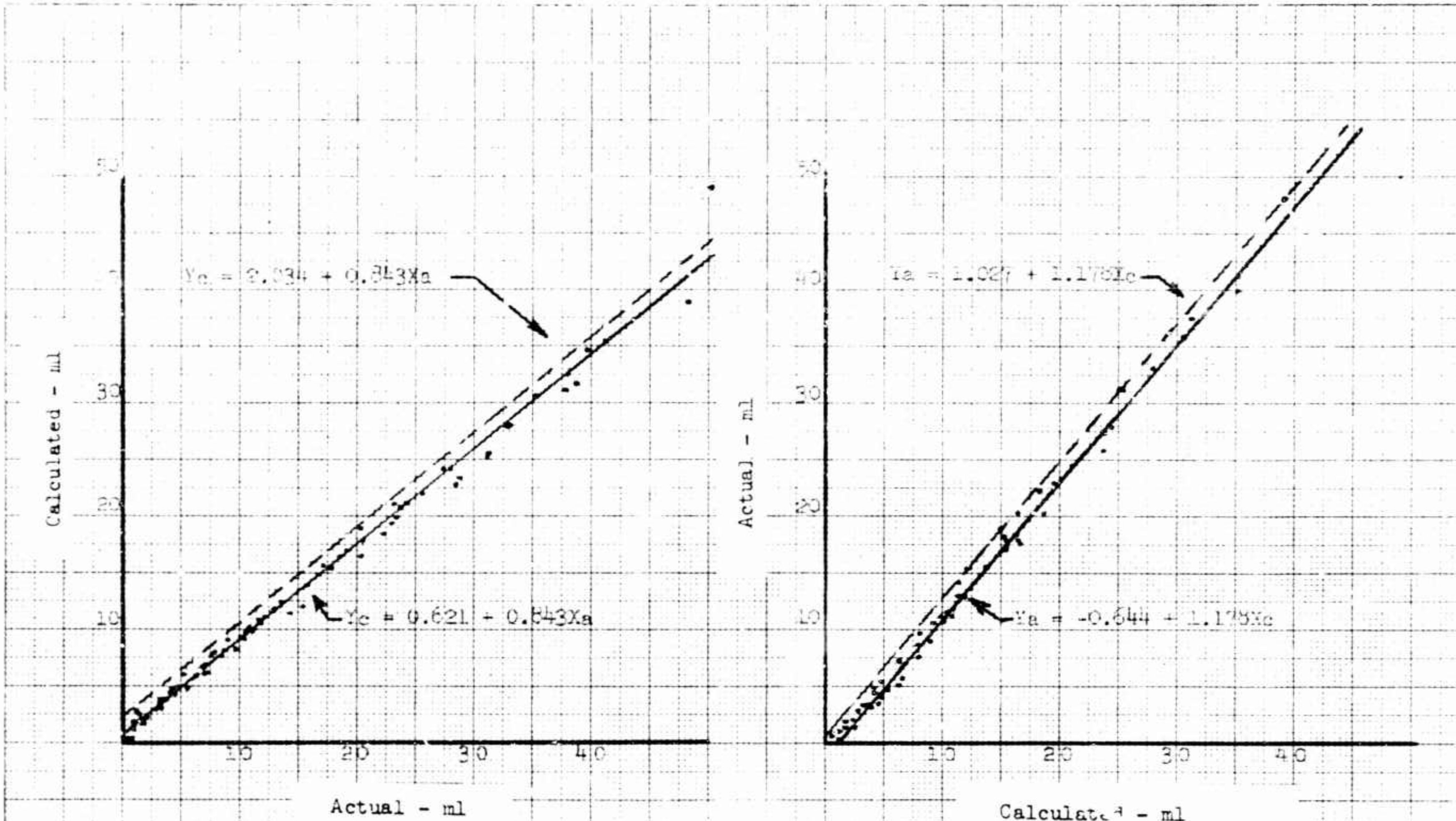

Figure 4. Relationship between Actual and Calculated (Nondestructive Method) Air Contents for 850-Gram Package

Appendix B were analyzed in a similar manner and as seen in Table II the linearity was again highly significant in each instance. The concomitant coefficients of correlation for all three size packages were also found to be significantly high. The test for significance was based on the 95% probability level.

Table II Comparison of Linear Fits and Correlation of Air Volumes in Packages

a. Actual (X) versus Calculated (Y)

Package Size	Linearity	Coefficient of Correlation	Standard Error
284 grams	Highly Significant	.994	0.702
568 grams	Highly Significant	.998	0.793
850 grams	Highly Significant	.996	0.852

b. Calculated (X) versus Actual (Y)

Package Size	Linearity	Coefficient of Correlation	Standard Error
284 grams	Highly Significant	.994	0.762
568 grams	Highly Significant	.998	0.872
850 grams	Highly Significant	.996	1.008

To convert readings obtained by either test method, an allowance must be made for error variability. In Figure 4, confidence levels (broken line) are shown as the limits of variability. The upper limits are based on the 95% confidence level and they were computed with the standard errors listed in Table II. One-sided limits were computed since specifications will normally require a maximum allowable air content in food packages. The graphical relationships of Figure 4 provide a means by which to estimate either Actual or Calculated air content values. More precise and impartial estimates are derived from equations. For this purpose, listed below are the equations for the regression and the upper 95% limit lines for each size package.

Equations for Estimating Calculated (Y_c) Air Content from Actual (X_a) Readings

Package Size	Linear Regression Line	Upper Limit Line
284 grams	$Y_c = 0.416 + .915X_a$	$Y_c = 1.205 + .915X_a$
568 grams	$Y_c = 0.418 + .907X_a$	$Y_c = 1.728 + .907X_a$
850 grams	$Y_c = 0.621 + .843X_a$	$Y_c = 2.034 + .843X_a$

Equations for Estimating Actual (Y_a) Air Content from Calculated (X_c) Readings

Package Size	Linear Regression Line	Upper Limit Line
284 grams	$Y_a = 0.033 + 1.079X_c$	$Y_a = 1.297 + 1.079X_c$
568 grams	$Y_a = 0.393 + 1.100X_c$	$Y_a = 1.053 + 1.100X_c$
850 grams	$Y_a = -0.644 + 1.178X_c$	$Y_a = 1.027 + 1.178X_c$

The repeatability of readings for the different size packages is compared in Table III at volumetric levels 5, 10, and 20 ml.

Table III Conversion of Volumetric Readings

a. Conversion from Actual to Upper Calculated

Package Size	Actual Reading (ml)	Upper Calculated Reading (ml)
284 grams	5	5.8
	10	10.5
	20	19.5
568 grams	5	6.3
	10	10.8
	20	19.9
850 grams	5	6.2
	10	10.5
	20	18.9

b. Conversion from Upper Actual to Calculated

Package Size	Upper Actual Reading (ml)	Calculated Reading (ml)
284 grams	5	3.5
	10	8.1
	20	17.3
568 grams	5	3.6
	10	8.1
	20	17.2
850 grams	5	3.4
	10	7.6
	20	16.1

The values listed in Tables IIIa and IIIb, above, were obtained from the equations discussed previously. For the three size packages, the ranges of differences in values converted at the 5-ml level are 0.5 ml (6.3 - 5.8) for the Upper Calculated reading, Table IIIa; and 0.2 ml (3.6 - 3.4) for the Calculated reading, Table IIIb. The corresponding ranges for the 10-ml level are 0.3 and 0.5; and for the 20-ml level, the ranges are 1.0 and 1.2. With the exception of one range, all others were within 1 ml.

As seen in Appendix B, the Actual air volumes are correspondingly higher than the Calculated values in most instances. The effect of any dissolved air in the package contents was discounted as a factor contributing to this difference. Its release under vacuum would tend to increase package buoyancy and thus P_2 would increase to maintain neutral buoyancy. As seen in equation (1) an increase in P_2 will also make V_1 larger. It was decided that this difference may be attributed in part to changes in daily atmospheric pressure and the water pressure on the package while it is submerged during the test. In addition to atmospheric pressure, it can be seen in Figure 2 that a water head Y also acts compressively on the package volume V. Assuming that the package remains suspended just below the water surface, the average pressure (w_p) can be derived as follows:

$$P = \int_0^y Duydy$$

where: P = total force on submerged area (uy)

D = density of water

u = unit width

y = depth of package measured in units of u

then $P = Duy^2/2$

The average pressure (w_p) on the package is estimated by dividing the area (uy) into the above equation for P.

$$w_p = Duy^2/2uy$$

$$= Dy/2 \qquad (3)$$

A similar pressure (w_p) will also influence the neutral buoyancy of the package when a vacuum is applied and the package remains floating just below the water surface. In Appendix A, buoyant force (B) equals the volume of package materials and contents (V'). Equations ii and iii, Appendix A, can be shown as:

$$D = W - B = W - V'$$

or

$$D = (W - V_m) - V$$

where V_m equals the volume of materials in the package not affected by pressure changes. Since the respective D values are obtained while the package is suspended in water, both atmospheric and water (w_p) pressures will act on V (air in package) and directly affect buoyancy. The weight of package (D) will depend on the depth location of the package from the water surface. Equation (4) below is derived from equation (1) by increasing P_1 and P_2 by the amount of w_p.

$$V_1 = \frac{(P_2 + w_p)\ D}{(P_1 + w_p) - (P_2 + w_p)}$$

$$= \frac{(P_2 + w_p)\ D}{P_1 - P_2} \qquad (4)$$

It is noted that V_1 is the calculated volume of air in the package at atmosphere plus the water head (w_p) pressure and it will require correction to atmospheric pressure (P_1) to permit comparison with the Actual volume which was derived from equation (2). Taking the V_1 value and substituting it into Boyle's Law:

$$(V_1 \text{ corrected})\ (P_1) = (V_1)(P_1 + w_p)$$

will tend to increase the Calculated volume (corrected) thus further narrowing the difference between the Calculated and Actual values. The magnitude of w_p depends on the package configuration (depth dimension)

Several specially prepared packages containing a plastic block were tested for residual air content. Results are shown in Table IV.

Table IV Effect of Water Head on Residual Air Content (ml)

Sample	Actual Volume (A)	Calculated Volume		Differences	
		I	II	I-A	II-A
1	16.20	15.80	15.40	-0.40	-0.80
2	11.66	11.54	11.20	-0.12	-0.46
3	15.55	15.60	15.30	+0.05	-0.25
4	26.70	26.60	26.20	-0.10	-0.50
5	29.40	29.41	29.01	+0.01	-0.39
6	8.35	8.21	7.90	-0.14	-0.45
7	7.13	7.25	7.00	+0.12	-0.13
8	5.91	6.05	5.80	+0.14	-0.11

Values under column I are based on calculations allowing for the water head w_p using equation (4); and values in column II were computed with equation (1). There was much closer agreement between the Actual and Calculated values when the water head w_p was considered in the computation. The differences are quite small (column I-A above) and they are also equally divided above and below zero as evidenced by the same number of plus and minus signs. The statistical paired t and sign tests indicate there is no significant difference between these results at the 95% level. However, if the w_p effect is ignored the Actual values can be expected to be higher. This is quite evident in Column II-A of Table IV where the difference between the Actual and Calculated values are consistently negative indicating that Actual values are higher.

It was not possible to achieve neutral buoyancy for some large size packages (850 grams) which contained a very low amount of air (in the order of 1 ml or less). This condition should not detract from the value of the test method for the following reasons:

a. If the air content is so low as to be inadequate to cause or sustain neutral buoyancy, the air volume in relation to the package size would in such instances meet specification requirements.

b. It is unlikely that a precise measurement of a very low volume of air can be made for a package containing actual foodstuffs using the conventional destructive method.

SUMMARY

The air content determinations derived with the nondestructive test data were repeatable and correlated well with actual residual air findings. It was also determined that an improvement in accuracy can be achieved by adjusting calculations for the effect of water pressure (w_p) on the submerged package. See equation (4). The need for and magnitude of this adjustment would be minimal for the smaller packages, by collecting data with the package positioned close to the surface of water; and to some extent, the w_p effect is neutralized by the buoyancy of the residual air bubbles clinging to the package surface (the small amount of air not completely removed by the wetting agent). If a test procedure is followed whereby test data are obtained with the package just below the water surface, a set of w_p values can be derived with equation (4) for the larger sized packages.

The results of this study substantiate the feasibility of developing specification criteria for this nondestructive test procedure. An example of applying such criteria to a specification is shown in Appendix C.

This nondestructive test procedure may provide significant savings in test inspection operations by:

a. Eliminating the need to reprocess or replace food products which would normally be contaminated or destroyed in the conventional test.

b. Preventing the destruction of packaging material.

c. Reducing over-all test time.

Personnel performing the nondestructive test will not require specialized laboratory skills. The procedure of the test is straightforward and does not require sophisticated test equipment.

APPENDIX A

Derivation of Equation*

1. Symbols Used

B = Buoyant force - volume of fluid displaced times the specific gravity of the fluid (weight of fluid displaced) (Archimedes Principle)

B_1 = Buoyant force in grams exerted on package contents and weights at P_1. (weight of water displaced)

B_2 = Buoyant force in grams exerted on package contents and weights (weight of water displaced) at P_2.

D = Weight of package, contents, and weights in water at P_1

D' = Weight of package, contents, and weights in water at P_2

T_k = Test temperature in ^{o}K

T_o = Standard temperature ($273^{o}K$) ($0^{o}C$)

P_o = Standard Pressure (760 mm Hg)

P_1 = Barometric pressure at time of test in mm Hg.

P_2 = Pressure in mm Hg at which test package (and weights) has neutral buoyancy with water

V_1 = Volume of gas in package at P_1

V_2 = Volume of gas in package at P_2

V_1' = Total volume of package, contents, and weights at P_1

V_2' = Total volume of package, contents, and weights at P_2

W = Total weight in grams of package, contents, and weights suspended in air

* Abstracted from Test Method RTM 829, Reynolds Metals Company, Packaging Research Division, dated January 19, 1966.

2. Derivation of Equation

Substituting symbols for Archimedes Principle: weight in water (D) = weight in air (W) - buoyant force (B) (weight of volume of fluid displaced) we obtain:

Equation i $D = W - B$

Since testing is done in water (specific gravity = 1.0) weight in water (D) = weight in air (W) - buoyant force (B) (weight of water displaced)

Equation ii $D = W - B_1$ at P_1

and similiarly

Equation iii $D' = W - B_2$ at P_2

But by definition at P_2, W equals the weight of water displaced

Equation iv $W = B_2$

Therefore effective weight of package and contents in water at P_2 is zero.

Equation v $D' = 0$

Again according to Archimedes Principle, the volume of the package, contents, and weights at P_1 equals the volume of the fluid (water) displaced and, since water = 1.0 specific gravity, equals the weight of the water displaced (B)

Equation vi $V_1' = B_1$

and similarly at P_2

Equation vii $V_2' = B_2$

then,

Equation viii $V_2' - V_1' = B_2 - B_1$

Since with changes in pressure on the package, the volume of gas will change according to Boyle's Law, but the volume of the solids and liquids will remain constant

Equation ix $$V_2' - V_2 = V_1' - V_1$$

or by transposing

Equation x $$V_2' - V_1' = V_2 - V_1$$

Substituting Equation x into Equation viii we get:

Equation xi $$V_2 - V_1 = B_2 - B_1$$

Substituting B_2 = W-D' and B_1 = W - D, from Equations ii and iii we get:

Equation xii $$V_2 - V_1 = (W - D') - (W - D) = D - D'$$

Since D' = 0 from Equation v, then,

Equation xiii $$V_2 - V_1 = D$$

When T is constant we know from Boyles Law that,

Equation xiv $$P_1V_1 = P_2V_2$$

or by transposing

Equation xv $$V_1 = \frac{P_2V_2}{P_1}$$

Subtracting both sides of the Equation from V_2 we obtain:

Equation xvi $$V_2 - V_1 = V_2 - \frac{P_2V_2}{P_1}$$

Substituting Equation xiii into Equation xvi

Equation xvii $$D = V_2 - \frac{P_2V_2}{P_1}$$

Solving for V_2 we obtain Lquation xviii

Equation xviii $$V_2 = \frac{D}{1 - \frac{P_2}{P_1}}$$

By substituting Equation xviii into Equation xv, we obtain

Equation xix $$V_1 = \frac{P_2 D}{P_1 \frac{(P_1 - P_2)}{P_1}}$$

Which simplifies to

Equation xx $$V_1 = \frac{P_2 D}{P_1 - P_2}$$

APPENDIX B

Test Results

1. <u>Residual atmosphere volume values for 284-gram packages</u>

Cal[1]	Act[2]	Cal	Act	Cal	Act	Cal	Act
.06	< .1[3]	.8	1.0	4.0	4.2	9.7	10.0
.12	< .1	1.2	1.2	4.3	4.4	8.9	10.5
.12	< .1	1.3	1.2	3.6	4.5	9.4	10.6
.13	< .1	.14	1.1	4.4	4.5	9.3	10.8
.13	< .1	1.3	1.2	4.4	4.6	10.1	11.4
.13	< .1	1.6	1.2	4.0	4.7	9.9	11.[illegible]
.13	< .1	2.1	1.2	4.4	5.1	9.2	11.9
.13	< .1	1.6	1.4	4.5	5.2	10.9	12.1
.13	< .1	1.5	1.5	5.0	5.3	10.9	12.4
.13	< .1	1.2	1.5	4.9	5.4	11.0	12.4
.13	< .1	1.8	1.7	4.8	5.5	12.2	13.2
.14	< .1	1.4	1.4	4.9	5.7	12.5	13.9
.14	< .1	1.5	1.6	5.4	5.8	12.3	13.9
.14	< .1	1.9	1.8	5.2	5.8	13.1	14.5
.14	< .1	1.5	1.8	5.6	6.0	11.0	13.6
.14	< .1	1.4	1.5	5.1	6.1	10.6	13.1
.14	< .1	1.9	1.9	5.6	6.3	13.0	15.0
.14	< .1	1.8	2.0	5.8	6.4	14.4	16.0
.16	< .1	2.2	2.1	8.4	6.4	14.8	16.4
.13	.1	2.1	2.3	5.5	5.9	17.0	16.7
.14	.1	2.3	2.3	5.9	6.5	13.4	17.4
.15	.1	2.3	2.3	6.0	6.6	14.3	17.5
.04	.2	2.4	2.4	6.8	7.4	15.4	17.6
.14	.2	2.7	2.8	7.2	7.4	17.9	19.7
.14	.2	2.3	2.9	6.7	7.7	19.8	21.0
.06	.2	2.7	2.9	6.9	7.9	19.0	20.6
.12	.2	2.9	2.9	7.3	8.0	20.0	21.6
.30	.4	2.7	3.1	7.7	8.2	20.3	21.9
.30	.4	3.0	3.2	7.7	8.0	20.0	22.[illegible]
.54	.4	3.[illegible]	3.3	7.4	8.3	24.4	24.0
[illegible]	.6	3.4	3.7	7.3	8.3	26.4	24.1
.7	.6	3.4	3.[illegible]	8.3	9.0	22.9	[illegible]
1.1	.7	3.7	3.9	8.3	9.0	26.5	28.[illegible]
0.6	.7	3.5	3.9	10.7	9.2	25.8	28.8
1.4	.9	3.3	3.4	8.8	9.3	10.6	12.7
2.2	.9	3.9	4.2	8.0	9.6		

1/Cal - Calculated Value
2/Act - Actual Value
3/For values indicated as < .10 a value of .05 was arbitrarily used for calculation purposes, in determining the difference between calculated and actual value of air volume.

2. Residual atmosphere volume values for 568-gram packages

Cal[1]	Act[2]	Cal	Act	Cal	Act	Cal	Act
0.3	0.0	3.3	3.4	11.5	10.9	20.3	21.4
0.3	0.0	4.0	4.0	10.8	10.9	19.9	21.4
0.3	0.0	3.9	3.6	10.0	11.2	19.7	22.3
0.4	0.0	4.3	4.1	11.4	11.6	19.8	22.7
0.3	< 0.1[3]	4.5	4.2	10.1	11.9	19.7	22.9
0.3	< 0.1	4.8	4.4	12.3	12.0	20.2	23.0
0.3	< 0.1	4.6	4.7	11.4	12.4	20.9	23.3
0.3	< 0.1	5.1	4.9	11.3	12.4	23.0	24.2
0.3	< 0.1	4.8	4.9	11.8	12.6	24.5	26.8
0.3	< 0.1	5.5	5.3	11.5	12.8	25.5	27.1
0.3	< 0.1	5.2	5.4	11.5	12.9	24.0	27.2
0.4	< 0.1	7.8	5.6	13.0	13.4	26.0	27.2
0.3	0.1	5.4	5.7	12.6	13.8	26.7	27.8
0.3	0.1	6.7	6.7	14.1	14.0	25.5	27.9
0.3	0.1	7.2	7.1	14.4	14.5	28.0	28.2
0.3	0.1	6.5	7.2	13.5	14.5	26.3	29.0
0.2	0.1	6.4	7.3	14.6	14.7	27.2	31.8
0.3	0.2	7.5	7.6	13.4	14.9	30.0	32.7
0.6	0.2	7.5	7.8	13.0	15.1	29.9	33.4
0.3	0.4	8.4	8.3	14.0	15.3	28.1	31.1
0.4	0.4	7.7	8.4	14.8	15.4	29.0	35.0
0.15	0.4	8.1	8.4	14.0	15.5	31.9	36.1
0.4	0.5	8.2	8.5	16.5	15.5	34.6	36.7
1.2	1.0	8.8	8.7	15.8	16.1	37.7	40.0
0.9	1.1	8.6	9.0	15.6	16.6	35.5	40.0
1.5	1.3	9.1	9.1	15.4	17.1	36.3	40.2
1.6	1.5	9.8	9.9	16.9	18.5	40.5	40.3
1.6	1.7	9.4	9.9	18.4	18.6	37.1	41.4
2.2	2.0	9.9	9.9	18.4	19.0	39.7	43.3
2.8	2.8	10.0	9.9	19.0	19.4	42.6	46.0
3.5	3.2	10.6	10.3	18.0	20.0	46.3	50.0
3.4	3.2	10.7	10.8				

1/Cal - Calculated Value
2/Act - Actual Value
3/For values indicated as < .10 a value of .05 was arbitrarily used for calculation purposes, in determining the difference between calculated and actual value of air volume.

3. <u>Residual atmosphere volume values for 850-gram packages</u>

Cal1/	Act2/	Cal	Act	Cal	Act	Cal	Act
.04	< .10 3/	3.1	2.7	7.7	7.5	17.1	19.2
.03	.10	3.0	3.2	7.9	8.0	18.7	20.2
.40	.10	3.1	3.2	7.7	8.5	16.5	20.3
.04	.10	4.0	3.2	8.1	8.8	17.8	20.5
.04	.10	3.5	3.4	9.1	9.1	18.4	22.2
.04	.10	3.9	3.4	8.3	9.7	19.4	23.0
.60	.10	3.1	3.4	9.3	10.0	21.1	23.1
.60	.10	3.9	3.5	9.8	10.4	20.8	23.7
.60	.10	4.6	3.5	10.2	10.7	19.9	23.4
.60	.10	4.6	3.9	9.2	10.5	21.2	23.3
.04	.15	4.6	4.0	9.7	11.0	21.0	24.4
.04	.20	4.1	4.1	10.5	11.7	21.9	25.4
.60	.20	4.4	4.2	11.1	11.9	21.8	25.5
.04	.30	4.2	4.3	10.8	11.4	22.1	25.5
.60	.30	4.8	4.3	11.0	12.1	23.7	25.7
.80	.40	5.0	4.5	11.4	12.5	24.0	27.2
.04	.40	5.0	4.8	11.3	12.6	24.3	27.7
.60	.60	4.2	4.5	11.3	12.7	24.0	27.7
.50	.70	5.2	4.8	11.4	13.0	22.7	28.3
1.70	.80	6.2	5.2	11.5	13.0	23.3	28.7
1.70	.90	4.8	5.5	11.8	13.0	25.0	31.2
1.30	1.20	6.4	5.9	12.5	13.6	25.5	31.2
1.70	1.20	6.6	6.4	11.4	14.2	31.3	37.3
1.70	1.40	6.5	6.6	12.0	15.4	31.1	37.4
1.70	1.40	6.4	6.8	13.7	15.8	35.3	41.4
2.60	1.40	6.3	6.6	14.7	16.5	39.0	48.1
2.40	1.70	6.2	6.7	14.9	16.9	34.7	39.7
2.10	1.70	6.7	6.7	15.6	17.1	27.9	32.6
1.80	1.80	6.7	7.1	16.7	17.6	30.5	35.5
2.80	2.70	7.1	7.2	15.3	17.9	32.2	37.9
2.90	2.70	6.2	7.3	16.5	17.9	31.5	38.7
3.00	2.90	7.6	7.4	15.2	17.8	49.0	50.8
3.10	3.20	7.6	7.5	16.4	18.5		

1/Cal - Calculated Value
2/Act - Actual Value
3/For value indicated as < .10 a value of .05 was arbitrarily used for calculation purposes, in determining the difference between calculated and actual value of air volume.

APPENDIX C

Specification Criteria for Nondestructive Test Method

1. The effect of air on the usability of food will limit the allowable amount of air for a specific package. The cases discussed in this Appendix illustrate with the 850-gram package the methodology by which specification criteria can be developed for the nondestructive test method after the technical considerations are completed and basic requirements are determined.

2. Specification criteria for the 850-gram food package:

a. Case No. 1 - The air amount in each 850-gram package is to be controlled; however, some allowance is permitted for packages containing air in excess of the prescribed level.

(1) Specification requirement - Assume the actual air requirement is set as 10.0 ml maximum. The equivalent nondestructive or calculated value is readily computed with the following equation as shown in Figure 4.

$$Y_c = 0.621 + 0.843X_a$$

Substituting 10.0 for X_a,

$$Y_c = 9.0 \text{ ml}$$

The requirement in the specification would specify that the maximum air amount permitted in the package shall be 9.0 ml when the test is conducted in accordance with the nondestructive method.

(2) Specification quality assurance provisions - In determining the acceptability criteria for inspection, an allowance must be made for variability in the test method. The equation for the upper limit in Figure 4 takes into account the random variations associated with the test procedure.

$$Y_c = 2.034 + 0.843X_a$$

Substituting 10.0 for X_a,

$$Y_c = 2.034 + 0.843\ (10.0)$$

$$Y_c = 10.5 \text{ ml}$$

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If the actual air content of a package were 10.0 ml, the above calculation indicates that there is only a 5-percent chance for the nondestructive reading to exceed 10.5 ml. The 10.5 value thus allows for expected variability. Should this value be exceeded, it can be assumed with a minimal risk that the package does in fact contain more than 10.0ml of air. The package would be unacceptable. The number of packages in the sample allowed to exceed the rejection criterion of 10.5 ml will depend on the Acceptable Quality Level or percent defectiveness specified for the test. The allowance for test variability and the rate of unacceptable packages permitted in a lot provide a low risk factor to the producer, i.e. the risk of rejecting his product if the air content in packages is actually 10.0 ml or less. In order to minimize the risk to the consumer, an additional provision should be considered whereby the average air content reading based on all sample packages tested must be equal to or less than the 9.0 ml value derived above.

b. Case No. 2

(1) A requirement is to be established for the nondestructive test method so that there is a minimal risk of accepting any package containing 10.0 ml or more air.

(2) The requirement for the nondestructive test method can be obtained from the upper limit shown in Figure 4 for the 850-gram package.

$$Y_a = 1.027 + 1.178X_c$$

Substituting 10.0 for Y_a

$$10.0 = 1.027 + 1.178X_c$$

$$X_c = 7.6 \text{ ml}$$

If a reading of 7.6 ml or less is obtained with the nondestructive method, there is a 5-percent or less chance that the actual air content in the package is 10.0 ml or more. The acceptance criterion would be established as 7.6 ml. If a reading above this value is obtained, the package would be rejected.